Augmented & Virtual Reality – Chances and Possibilities for Smart Energy Supply

Johann Schrammel, AIT Austrian Institute of Technology GmbH
Georg Regal, AIT Austrian Institute of Technology GmbH
Peter Fröhlich, AIT Austrian Institute of Technology GmbH

Contact: johann.schrammel@ait.ac.at

Abstract – Virtual and augmented reality systems have become more mature in the recent years and are about to enter domains besides pure research. Important characteristics of these technologies make them a promising approach also for the energy sector. In this paper we provide an overview of existing systems, describe their main characteristics and typical application domains and report example systems that have been implemented in the energy domain.

1. Introduction

The term "Virtual Reality" (VR) is used to describe a series of completely different techniques. The spectrum ranges from digitally processed images to immersive, interactive 3D worlds. The basic principle in all cases is the digital reproduction of an infrastructure. Augmented Reality (AR), on the other hand, is the addition of digital artifacts to the real world. For example, virtual objects are faded into the user's field of vision. Up to now, VR and AR have been a niche product. This is set to change, as recently more and more off-the shelf technologies have been released for the consumer market, thus making VR and AR experiences affordable for a broad range of application scenarios. Oculus has delivered their first consumer version of a VR-Headset in March 2016, and HTC in cooperation with Valve (Vive) and Sony (Playstation VR aka Morpheus) followed soon. With the market launch of these glasses, the demand for more "serious" applications is also growing beyond the gaming industry. VR not only allows the presentation of the shape, but also enables testing under different conditions or in different environments. Car manufacturers such as Audi and Volvo have already realized that customers will be able to use expensive extras more quickly if they experience their capabilities realistically beforehand. VR can thus help decision-makers and planners to get to know more radical design ideas and innovations in Smart Street Design and to convince them more easily.

Although there is still room for technical improvements, VR and AR technology is often seen as a disruptive technology that will influence large parts of the economy, and we think that there are also important possibilities, chances and consequences for the utilities industry and energy sector. In this paper we would like to provide a brief overview on the spectrum of VR/AR systems, on currently available products and discuss possible implications for the energy sector.

1.1 The Reality – Virtuality Continuum

In order to better understand and systematize the characteristics of different virtual and augmented reality approaches we think it is helpful to refer to the conception of a Reality – Virtuality Continuum as introduced by Milgram et al [11]. They defined a Reality – Virtuality Continuum that provides a good model for classification of VR and AR technology and applications. The difference between VR and AR can be seen as a continuum. On the one end of the continuum is full VR on the other end plain reality the space in between is defined by Milgram et al. as mixed reality and includes Augmented Reality (AR) and Augmented Virtuality.

If the user is full immersed in a completely synthetic / virtual world we use the term VR. Recent examples for fully immersive commercial systems are head mounted displays like Oculus Rift[1], HTC Vive[2], or Google Cardboard[3]. A good overview of the current state of the art in VR is provided by Anthes et al. [1], although in this fast evolving market this will most likely be outdated soon. Currently commercial available VR solutions can be divided into cable bound HMD and wireless HMDs. Wireless HMDs are mostly special smartphone cases with two lenses. On the smartphone a stereoscopic image is displayed and can be viewed through the lenses. Tracking of the head movement and rendering of the corresponding field of view is done by the sensors of the smartphone. The biggest advantage of wireless HMDs is, that they are relatively cheap and can thus be distributed widely e.g. Google Cardboard. Also as no cable and PC is needed wireless HMDs are truly mobile. On the negative side computation power of current smartphones is not sufficient for providing a fully immersive experience.

The second category are cable bound HMDs that are used in combination with a powerful desktop PC or laptop e.g. HTC Vive or Oculus Rift. Tracking is done by inertial sensors and external tracking technology. Biggest advantage are the possibility to provide fully immersive experiences in complex virtual environments and the possibility to walk around in the virtual environment. Biggest disadvantage are the relatively high costs that limit scalability. If users are fully immersed in a Virtual Environment but certain real objects are still present according to Milgram et al. [11] it can be defined as Augmented Virtuality, although that term is not as widely used as VR or AR. A recent technological example for Augmented Virtuality are the Vive Trackers[4] developed by HTC that enable the usage of real objects in a virtual environment.

If the user is acting in a real world environment that is augmented with additional digital content we speak of Augmented Reality. An example for AR applications is the popular commercial game

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[1] https://www.oculus.com/

[2] https://www.vive.com/

[3] https://vr.google.com/cardboard/

[4] https://www.vive.com/us/vive-tracker-for-developer/

Pokemon Go. In Pokemon Go digital characters (Pokemons) are blended seamlessly into reality (captured through the smartphones camera, thus providing the illusion that the virtual object is a part of the environment. A comprehensive overview of the state of the art in AR technology is provided by Billinghurst et al. [4]. Currently available commercial examples are regular smartphones used as AR devices or head worn glasses like e.g. the Microsoft HoloLens[5]. Positioning of virtual objects in reality can be done through a broad range of technologies – cf [4] for example by markers (e.g. Vuforia framework[6]), GPS positioning (e.g. Pokemon Go[7]) or depthcameras (e.g. Microsoft Hololens).
Figure 1 below shows this continuum from the real to the virtual environment with possible examples and application scenario taken out of the energy context: Left we see a lineman working in his physical environment, next a worker using a headset with micro-display (augmenting him with context information) is shown[8]. Another possible application uses a CAVE-Environment [2], and on the right an example for full virtuality is shown [10].

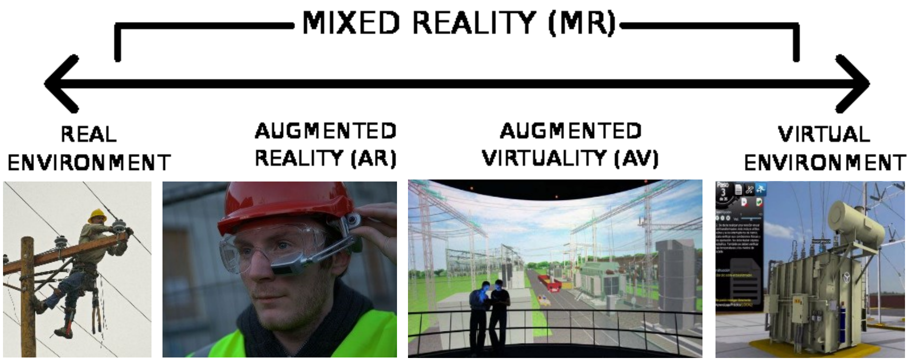

Figure 1: The continuum of real and virtual environments

We can conclude, that AR and VR technology has evolved from a niche in research towards a broadly available product that can be used in a broad range of application scenarios. Although gaming is currently the main reason for the rapid evolvement of AR and VR technology more "serious" application areas for VR and AR are catching up such as training [5] and assistance for maintenance and production [9].

[5] https://www.microsoft.com/en-us/hololens

[6] https://www.vuforia.com/

[7] http://www.pokemongo.com

[8] http://www.kopin.com/offerings/headset-solutions

2. Applications of AR and VR in the energy industry

Considering these characteristics of Virtual and Augmented Reality systems it is not surprising that promising concepts and prototypes in the utilities industry have been suggested and developed. And in fact, the energy domain has a strikingly large share in the portfolio of application opportunities presented and explored by research institutes and companies. Many advantages of AR and VR are especially exploitable for this sector, as it employs a large workforce that is active in the field. This group of users' needs orientation and spatial guidance enabled by AR, extra safety information in a challenging natural and technological environment (see some example projects in section 2.1). Furthermore, the opportunities of spatial mapping of information by VR offers a reduction of complexity for specialized operators, who have to deal with an increasingly complex and distributed infrastructure (see section 2.2). Furthermore, the opportunities of spatially-encoded intuitive and context-embedded knowledge transfer leveraging an increasing number of VR- and AR-based training courses (see section 2.3**Fehler! Verweisquelle konnte nicht gefunden werden.**). There are also further uses of VR in the energy domain, which includes planning support (e.g. exploring opportunities for the exact placement of a substation) and public dissemination (such as enabling citizens to preview future wind turbines in their neighborhood and participate in the decision process).

2.1 Supporting field workers

In the field and on the spot, AR has obvious advantages, as the field-worker's view of the physical surroundings can be superimposed with otherwise invisible or inaccessible digital information. Examples for such information would be real-time data or feedback from the control center or could be a useful way to decrease the load of field workers.

Already in 2009, Schall et al. [14] presented a functional handheld augmented reality system that visualized underground infrastructure for water supply for field workers of a utility company. Opris et al. [12], for example, mention the in-situ visualizations of real-time data measurements and SCADA applications, specific information from other dependent systems, design plans of sub-stations, or step-by-step instructions for the next actions. Also, AR could help to avoid risks, such as visualizing invisible poisonous gas that had evaded from a leak, or by indicating low levels of insulation oil. Another use of AR is the communication and documentation by field workers at the premises of utilities or at the customer.

2.2 Supporting control operators and maintenance staff

For operators in control rooms, who have to deal with a large mass of abstract information related to remote spaces, VR has been explored to decrease complexity. For example, virtual reality techniques were considered for routine monitoring and control in power systems operations, such as showing the operation and status of substations in an intuitive way [7]. Cardoso et al. [6] state that inspecting realistic and digitally annotated 3D models of substations should be much less demanding than analyzing 2D diagrams. From a business side, VR-products are being offered for VR-based asset management (see Virtalis.de). But also AR has been proposed as a means to provide tailored data in a contextually relevant way, in order to support human operators [12].

2.3 Education and training

One of the most active and promising application domains for VR and AR is training. Due to the large scale demand of skill acquisition in the energy field in various fields, the training industry is constantly looking for more advanced, efficient and safe methodologies. To this end, the characteristics of VR and AR are especially appealing: these techniques allow learners to interact with the content, and they are no longer an observer but can touch and feel the experience which enhances learning and supports understanding.

Another important aspect is that the training system can address situations that are otherwise difficult or impossible to implement in a training scenario. In the same ways as medical students can try their first surgeries without injuring patients and future astronauts can get ready for the next space mission, maintenance workers can train in hazardous environments without real danger. Due to this factors using VR/AR also has the potential to significantly reduce the costs of training.

Since relatively recently there is a number of commercial providers of VR and AR products for the energy industry, and some of these show impressive demos and use cases on their web portals. Training contents can range from setting up offshore wind turbines, installation and setup activities in urban as well as in industrial environments, working routines at production sites, crisis and emergency response, or technical details of equipment such as substations.

In the following paragraphs we present two approaches and example systems taken from different end points of the continuum from reality to full immersion in order to illustrate the whole spectrum of potentials.

2.3.1 Non-immersive environment: A training system for maintenance of high power live-lines

Several virtual reality based training systems have been developed in order to capitalize the potentials of virtual reality approaches for training purposes. An example system is the ALEN 3D system [10] [], which is in use since several years for training purposes of the Mexican electric utility company. The training is focused on the maintenance of high power live-lines in a distribution system.

The training system provides simulation facilities which consist of interactive 3D representation of the actual work environment and allow the trainee to interact with the system in a realistic way, even in abnormal operation and emergencies. 3D models of the different relevant elements (equipment, materials and tools) are modeled as 3D shapes to scale and have a realistic appearance. The created virtual scenes are enhanced with animation, interactivity and audio. The user interacts with the virtual world using conventional interaction devices (a computer mouse), which allow him to select and manipulate mouse-sensitive 3D objects. Valid clicks trigger 3D animations that show how to install the materials, how to operate the equipment and the location where the technicians should be placed. The system is training thousands of live-line operators from the 13 divisions of distribution system of the Mexican electric utility company.

2.3.2 Full immersion: A training systems for live-line workers

Work in power systems should be free of interruption as much as possible, so it is carried out by live-line techniques. VR-based training systems provides the possibilities for cost-effective training and guarantees safety during training operations. Park et al [13] developed a virtual reality based training system (VRTS) for live line workers that consisted of a HMD, sensing glove, and a spatial tracking system. Objects involved in virtual live-line work environment are modeled as 3D shapes. The target scenario is the live-line Cut-Out-Switch (COS) replacement work. This work is typically done at the top of the pole in an insulated bucket truck. Similar to the realistic context in this system the trainee can move his or her own position, as if he or she were in the bucket truck, by using voice commands such as “up,” “down,” “left,” and so on. To increase the sense of reality, also different electric phenomenon such as electric sparks are implemented. The developed training system has been tested by 24 linemen with realistic tasks such as the insulation of the power line on the pole or the installation of a bypass jumper cable. Most participants reported that the developed system is effective and adequate to complement the current training process, but also that further improvements of the technology (especially haptic feedback) would increase the systems usefulness.

3. Outlook and Conclusions

Virtual and augmented reality hard- and software technology has reached a level of maturity and affordability that makes it already viable and scalable for practical application in a wide range of industrial contexts. Besides visual fidelity, especially the advances in haptic interactions that make it so appealing for many purposes. Especially for (electrical) energy utilities, there is a range of problems that can well be addressed by virtual and augmented reality services. Beyond the specialized application fields mentioned above, it appears important to blend and entangle VR and AR technology with existing processes and solutions. For example, the paradigm of blended learning should be followed, rather than embarking on stand-alone solutions, such that the strengths and weaknesses of traditional training, non-immersive and immersive VR and real-world training are combined in a suitable way.

Many of the above proposed approaches for using VR or AR for application energy domain are so far in a conceptual stage. Still, most companies restrict their staff to use standard hardened laptops, tablets or mobiles. However, along with the growing interest in and maturity of this technology, we expect that wearable devices along with VR and AR equipment will be applied to enable hands-free modes for the complex and dangerous tasks that utility workers are engaged in.

The overarching success factor besides the actual technological maturity of VR equipment and the fidelity of content rendering, is whether the training strategy itself is properly designed and embedded in the application context as well as the available interaction opportunities and constraints. In order to achieve a high uptake rate, satisfactory learning effects, systematic user-centered design and accompanying evaluations are needed.

References

[1] Anthes, C., García-Hernández, R. J., Wiedemann, M., & Kranzlmüller, D. (2016, March). State of the art of virtual reality technology. In *Aerospace Conference, 2016 IEEE* (pp. 1-19). IEEE.

[2] Arendarski, B., Termath, W., & Mecking, P. (2008). Maintenance of complex machines in electric power systems using virtual reality techniques. In *Electrical Insulation, 2008. ISEI 2008. Conference Record of the 2008 IEEE International Symposium on* (pp. 483-487). IEEE..

[3] Ayala García, A., Galván Bobadilla, I., Arroyo Figueroa, G. (2016) Virtual reality training system for maintenance and operation of high-voltage overhead power lines. Virtual Reality (2016) 20.

[4] Billinghurst, M., Clark, A. and Lee, G. (2015) A Survey of Augmented Reality. Foundations and Trends® in Human–Computer Interaction 8, 2–3: 73–272.

[5] Bossard, C., Kermarrec, G., Buche, C. and Tisseau, J. (2008) Transfer of learning in virtual environments: A new challenge? Virtual Reality 12, 3: 151–161.

[6] Cardoso A., Prado P.R., Lima G.F.M., Lamounier E. (2017) A Virtual Reality Based Approach to Improve Human Performance and to Minimize Safety Risks When Oper-ating Power Electric Systems. In: Cetiner S., Fechtelkotter P., Legatt M. (eds) Advances in Human Factors in Energy: Oil, Gas, Nuclear and Electric Power Industries. Advanc-es in Intelligent Systems and Computing, vol 495. Springer, Cham

[7] Carvalho, A. et al., "A methodology for reducing the time necessary to generate virtual electric substations," 2016 IEEE Virtual Reality (VR), Greenville, SC, 2016, pp. 163-164. doi: 10.1109/VR.2016.7504704

[8] Galvan, I., Ayala, A., Muñoz, J., Salgado, M., Rodríguez, E. and Pérez, M. (2010) Virtual Reality System For Training Of Operators Of Power Live Lines. Proceedings of the World Congress on Engineering and Computer Science Vol I.

[9] Gavish, N., Gutierrez, T., Webel, S., Rodriguez, J., & Tecchia, F. (2011). Design guidelines for the development of virtual reality and augmented reality training systems for maintenance and assembly tasks. In *BIO web of conferences* (Vol. 1, p. 00029). EDP Sciences

[10] Hernández, Y., Pérez-Ramírez, M., Zatarain-Cabada, R., Barrón-Estrada, L., & Alor-Hernández, G. (2016). Designing Empathetic Animated Agents for a B-Learning Training Environment within the Electrical Domain. Educational Technology & Society, 19(2), 116–131

[11] Milgram, P., Takemura, H., Utsumi, A. and Kishino, F. (1994) Augmented reality: a class of displays on the reality-virtuality continuum. Telemanipulator and Telepresence Technologies 2351: 282–292.

[12] Opriş, I., Costinaş, S., Ionescu, C. S., & Nistoran, D. E. G. (2017, March). Towards augmented reality in power engineering. In Advanced Topics in Electrical Engineering (ATEE), 2017 10th International Symposium on (pp. 39-44). IEEE.

[13] Park, C., Jang, G. & Chai, Y. (2006) Development of a Virtual Reality Training System for Live-Line Workers. International Journal of Human–Computer Interaction Vol. 20 , Iss. 3.

[14] Schall, G., Mendez, E., Kruijff, E. et al. Handheld Augmented Reality for underground infrastructure visualization. Pers Ubiquit Comput (2009) 13: 281. https://doi.org/10.1007/s00779-008-0204-5

Johann Schrammel, Scientist at AIT in the Center for Technology Experience, studied education science, sociology and group dynamics, holds a Master degree in adult education from University of Graz. Johann is active in the field of HCI since 2001 and is the author of more than 50 peer-reviewed publications. In his research he has addressed different questions of the interactions of humans and technology, recently with a specific focus on behaviour change and the energy sector. He has successfully led numerous national and international research projects, focusing on different topics such as interacting with intelligent systems, information visualization, persuasion and user experience.

Peter Fröhlich is a Senior Scientist at AIT and leader of a research team on technology acceptance in ubiquitous and mobile contexts. His research interest are mobile spatial interaction and persuasive technologies for the promotion of sustainable and safety-aware behavior. Peter received a doctoral degree in Applied Psychology in 2007 and works in the area of Human-Computer Interaction and Ubiquitous Computing for more than 15 years. He is co-author of more than 70 scientific contributions and regular organiser, editor and reviewer of several renowned journals and conferences, such as the journal of Ubiquitous Computing, Mobile HCI, Automotive UI and CHI.

Georg Regal, Scientist at AIT in the Center for Technology Experience, studied medical informatics at the technical university of Vienna. His research interest are interface and interaction-design, especially in the domain of human augmentation for special application contexts and user groups. Georg has gathered experience in the design, development and evaluation of AR and VR systems in multiple research projects. Examples are evaluation in VR (Moving Project), VR /AR supported participation in urban planning (VR Planning Project) and VR /AR training for industrial workers (NAFI4.0 Project).